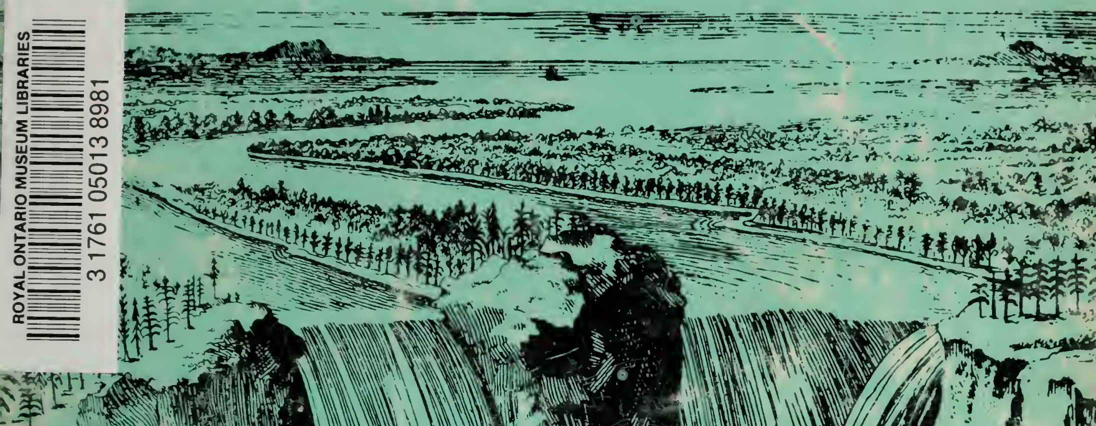
P.S.
Ro
672
no.9

T? Why? WHEN? HOW? WHERE? WHO?

Niagara Falls: STORY OF A RIVER

ROYAL ONTARIO MUSEUM LIBRARIES
3 1761 05013 8981



WALTER M. TOVELL

Royal Ontario Museum / University of Toronto

I keep six honest serving-men

(They taught me all I knew);

Their names are WHAT *and* WHY *and* WHEN

And HOW *and* WHERE *and* WHO. RUDYARD KIPLING

ROYAL ONTARIO MUSEUM SERIES

WHAT ? WHY ? WHEN ? HOW ? WHERE ? WHO ?

1 *K. B. Brett:* WOMEN'S COSTUME IN EARLY ONTARIO
2 *Gerald Stevens:* EARLY ONTARIO GLASS
3 *Walter M. Tovell:* THE NIAGARA ESCARPMENT
4 *R. R. H. Lemon:* FOSSILS IN ONTARIO
5 *W. E. Swinton:* DINOSAURS OF CANADA
6 *L. S. Russell:* THE MASTODON
7 *W. E. Swinton:* EVOLUTION
8 *Winifred Needler:* JEWELLERY OF THE ANCIENT NEAR EAST
9 *Walter M. Tovell:* NIAGARA FALLS: STORY OF A RIVER
10 *E. S. Rogers:* THE FALSE FACE SOCIETY OF THE IROQUOIS
11 *A. D. Tushingham:* THE BEARDMORE RELICS: HOAX OR HISTORY?
12 *L. S. Russell:* LIGHTING THE PIONEER ONTARIO HOME
13 *Gerald Stevens:* EARLY ONTARIO FURNITURE
14 *K. B. Brett:* WOMEN'S COSTUME IN ONTARIO (1867–1907)

© The Governors of the University of Toronto, 1966

This series was edited in the Information Services of the Royal Ontario Museum by Ian Montagnes. It was designed by Harold Kurschenska, and printed at the University of Toronto Press. Drawings in this booklet are by Paul Geraghty, ROM artist craftsman. Photographs: page 3, Ontario Department of Tourism and Information; page 7 (bottom), G. K. Gilbert, United States Geological Survey; page 11, Buffalo and Erie County Historical Society; page 15, Walter M. Tovell.
COVER: Niagara Falls as they appeared in 1678 to Father Louis Hennepin, the first European to describe them. This engraving originally appeared in Hennepin's *A New Discovery of a Vast Country in North America*, published in 1698. From the Sigmund Samuel Canadiana Collection of the Royal Ontario Museum.

Quotation from THE JUST SO STORIES *by Rudyard Kipling, by permission of Mrs. George Bambridge and The Macmillan Company of Canada Limited*

LIBRARY
ROYAL ONTARIO MUSEUM
UNIVERSITY OF TORONTO

WHAT? HOW?

Why? WHERE?

WHEN? WHO?

Niagara Falls: Story of a River

by WALTER M. TOVELL

> I could not conceive how it came to pass, that
> four Great Lakes, the least of which is 400
> Leagues in compass, should empty themselves one
> into another, and then all centre and discharge
> themselves at this Great Fall, and yet not
> drown a good part of *America.*

WHAT is it that came to pass?

The words with which this story begins were written nearly 300 years ago by the first European to describe Niagara Falls. Father Louis Hennepin was a Recollet missionary friar of New France. In 1678, as one of a group of explorers under the Sieur de la Salle, he followed a sound of thunder and a pillar of mist to their source—and encountered one of the seven natural wonders of the modern world. The awe with which Father Hennepin recounted the sight of the great cataract, cascading thousands of tons of water into a picturesque gorge, has been echoed many times. Long before they became a favourite of honeymooners, the Falls were attracting visitors from many lands and many walks of life. Almost from the beginning they inspired artists and poets.

. . . I should wander here
In musing awe; should tread this wondrous world,
See all its store of inland waters hurl'd
In one vast column down Niagara's steep;

—THOMAS MOORE, 1804

Spectacular power was, however, only one part of the fascination of the Falls. Beyond that lay the mystery of their origin. For more than a century science had no way of explaining how such a phenomenon could occur. About 100 years after Hennepin, another early visitor marvelled:

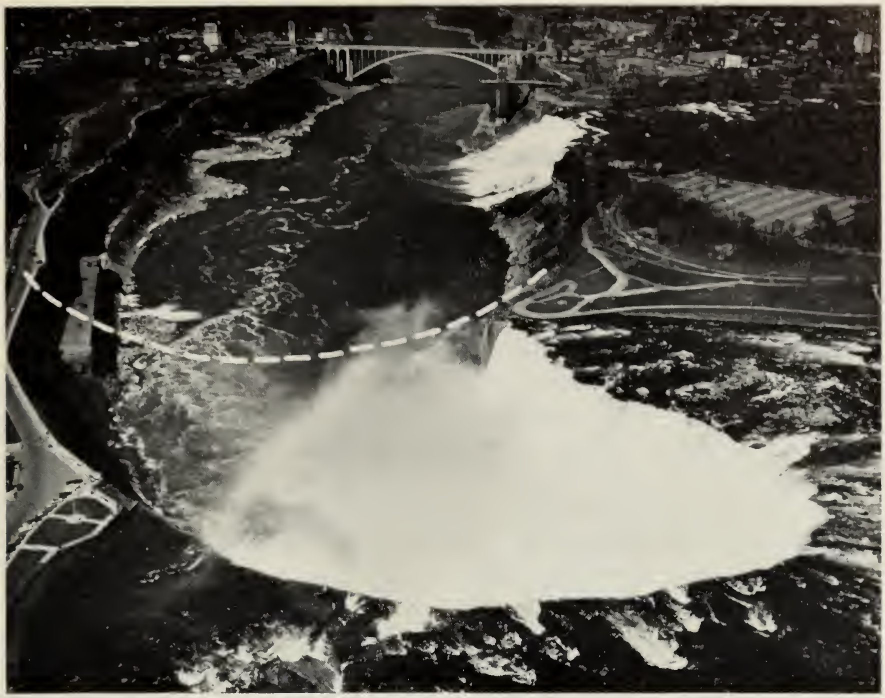
> It is surely a wonderful fact in geography, that a river, very near 2,500 feet wide, and generally fifteen in depth, should find the level of its channel suddenly sink beneath its stream, and should throw down its entire mass of water, from a height of a hundred and forty-four feet, into a channel through which it pursues its subsequent course, where the spectator can discover no hill or ridge that could once have restrained or blocked up its passage.

In time, geologists produced the answer. The Falls and the seven-mile gorge below them were part of a long-continuing process. At its beginning, many thousands of years earlier, the ancestral Niagara River had poured over the rim of the Niagara escarpment just above the present site of the village of Queenston. Gradually the tumbling waters had eroded a channel into the bedrock, to form the gorge and push the Falls ever closer to Lake Erie.

The process of gorge formation and the explanation for the present position of the Falls were straightforward. Still there were ramifications that flew in the face of popular religious beliefs. Between the 17th and 19th centuries, many people thought they could tell exactly when the earth had been created. From Biblical evidence a distinguished Irish archbishop, James Ussher, had determined the date as October 23, 4004 B.C.—at 9 A.M. But how could the Niagara Gorge have been cut since then? Robert McCauslin, who had lived at the Falls for nine years, set out the argument in a speech to the American Philosophical Society in 1789.

> It is universally believed that the cataract was originally at this ridge [the Niagara Escarpment], and that it has by degrees worn away and broke down the rock for the space of these six or seven miles. Some have supposed that from these appearances, conjectures might be formed of the age of this part of the world. . . . If we adopt the opinion of the Falls having retired six miles, and if we suppose the world to be 5,700 years old, this would give about sixty-six inches and a half for a year, or sixteen yards and two-thirds for nine years, which I venture to say has not been the case since 1774.

When dogma and geological theory came into conflict, the former was the first to find favour. Was it not more likely, Ussher's supporters asked, that



White dashes outline the estimated position of Niagara Falls in 1678, when Father Louis Hennepin discovered a "vast and prodigious column of water, which falls down after a surprising and astonishing manner, inasmuch that the Universe does not afford a parallel." Progressive erosion has carried the Falls back to their present position. The entire length of gorge visible in this photograph has been carved out since the birth of Christ.

the gorge was the result of "terraqueous convulsions" or a single "revolutionizing struggle"—that in fact the entire operation had taken, not millennia, but only a month, or perhaps a day?

But others used the Falls as evidence to challenge Ussher's figures. As early as 1790 the age of the Falls was estimated at 55,440 years, and this was used in an attempt to account for the age of the world. A little later another theoretician used the Falls to calculate a period of time of 36,960 years "since the first rain fell upon earth".

WHO finally explained what had come to pass?

The controversy eventually was resolved by Charles (later Sir Charles) Lyell, a great British scientist who was one of the fathers of modern geology. In 1841, he visited Niagara Falls and demonstrated beyond a shadow of a doubt that they had eroded the gorge. The task, he said, might have required 35,000 years; but the escarpment, he noted, was much older.

Lyell was joined in his conclusions by an American, James Hall, an equally eminent geologist, whose field studies included the first triangulation survey of the Falls. Hall reported in 1843 that the river had been "the great agent in excavating its own channel". Like Lyell he added that the Falls, in geological time, were very young.

While the process of gorge formation occupied most of the attention of the early investigators of the Niagara River, two other important features emerged. The first, found by Lyell, is known as St. Davids Gorge. This is the buried channel of an ancestral Niagara River which extended northwesterly from the present Whirlpool towards Lake Ontario, in line with the Whirlpool Rapids Gorge and approximately at right angles to the lower half of the present river. The second feature, which was apparent only after detailed mapping, is that the width of the gorge and depth of the river vary considerably between the Falls and the escarpment edge.

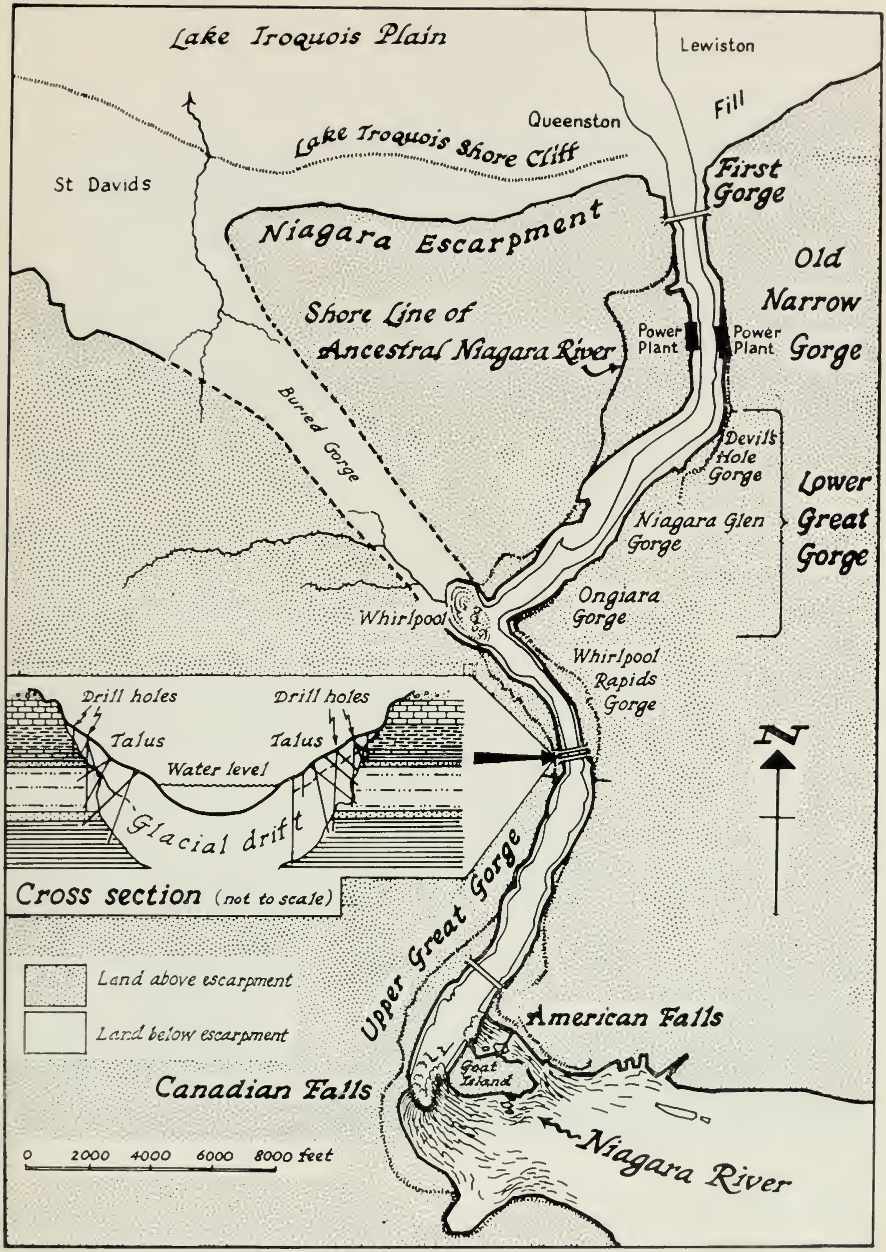
The origin of the Niagara River as the drainage link between Lake Erie and Lake Ontario remained unsolved until the last quarter of the 19th century, when its evolution was fitted into the geological history of North America, and in particular to that part of the continental history which deals with Pleistocene glaciation, the Great Ice Age. As the concepts of this glacial epoch developed so did the realization that the Great Lakes, as they are known today, along with their associated drainage, evolved with the final retreat of the ice sheet. The evidence was provided by the work of great pioneer North American geologists, notably A. P. Coleman, H. L. Fairchild, G. K. Gilbert, F. Leverett, J. W. W. Spencer, and F. B. Taylor.

Today Niagara Falls and the Niagara River are recognized as products of the last phases of Pleistocene glaciation. The gorge is nothing more than a big trench, incised into the Niagara escarpment since the glaciers retreated from the Niagara Peninsula. But these facts only add to the wonder of the Falls.

HOW did it come to pass?

What surprised early visitors even more than the power of the waterfall was its relationship to the land surrounding it. The Falls might not have seemed so remarkable in a mountainous setting, where great cataracts might normally be expected; but here the land was flat and even, both above and below the drop. Why doesn't the river follow an even grade between Lake Erie and Lake Ontario?

The answer to these questions lies in the relationship of the Niagara River to the Niagara escarpment, and the varying degrees of hardness of



The Niagara Area. The cross-section at the railway bridges reveals deposits of glacial drift—evidence that this portion of the Whirlpool Rapids Gorge has been re-excavated. (See page 8) the strata that form the escarpment bedrock (see No. 3 in this series: *The Niagara Escarpment*). Had these rocks been of uniform hardness, the Niagara River would undoubtedly have had a different form. But they are not: some are hard sandstone, limestone, and dolomite, which is a rock akin to limestone; others are soft shale and shaly limestone. The layers of hard rock form ledges and cliffs along the walls of the gorge, and in some instances produce overhanging cliffs. The softer layers support vegetation.

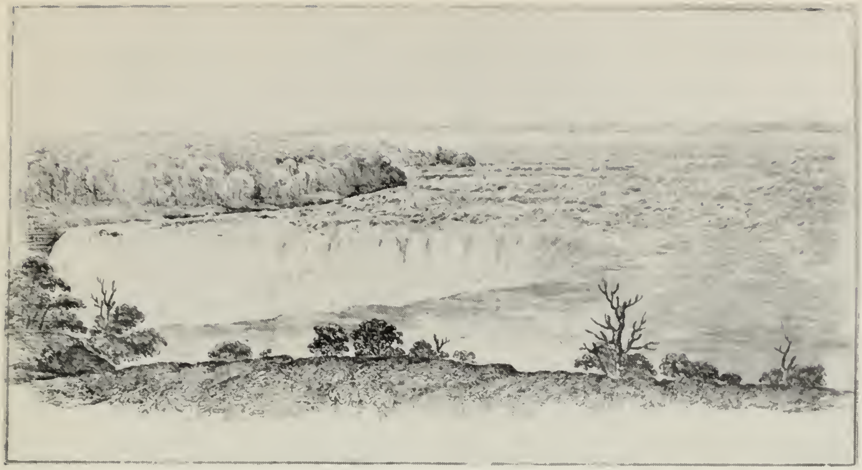
The top formation of the Niagara escarpment in general, and of the Niagara gorge in particular, is a hard dolomite—the Lockport dolomite. Immediately beneath it is the softer Rochester shale. These two formations are the only ones exposed around the Falls. The hard dolomite is not greatly affected by the erosive action of the water but the shale supporting it gradually is worn away. In time the rim becomes undermined. It then abruptly collapses in great rock falls, the cataract moves a step further upstream, and a vertical face is maintained. This process of retrocession was recognized at least as early as 1809.

Today geologists call this process *sapping*. They recognize that other factors contribute to its progress, in particular the fact that water, working along the bedding planes and joints of the rock layers, freezes during the winter; the resulting expansion quickens the formation of the rock falls. The chunks which fall to the base of the Falls form a heap, or talus. While this is a continuous process, unusually large rock falls occur from time to time. The most recent, in 1956, destroyed part of the Schoellkopf Power Plant below the Rainbow Bridge.

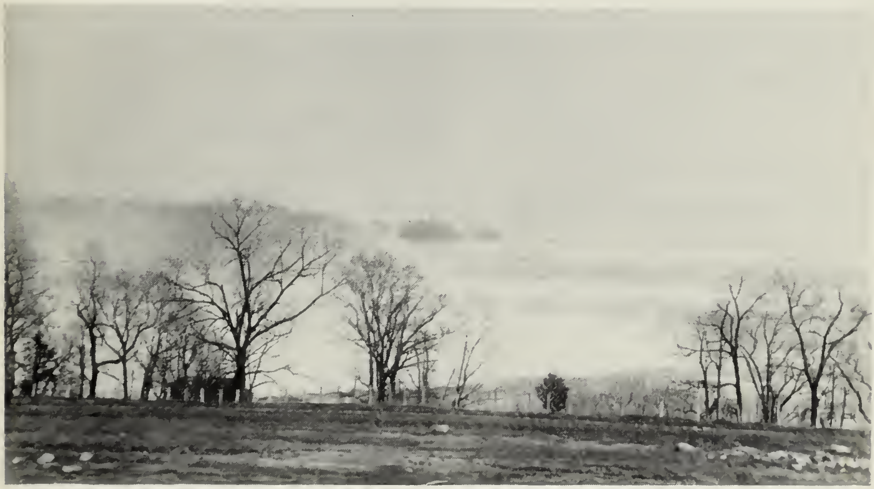
The strata underlying the Rochester shale are exposed downstream from the Falls; the complete sequence is visible at the mouth of the gorge. While it cannot be done precisely it is no trick of the imagination to envisage the Falls in their original position at Queenston, at the time when they started cutting the gorge. They must have been much higher then than they are today, and as they worked back their profile varied quite considerably because of the role played by the strata. Not until the waters of the river reached an elevation equal to the base of the Rochester shale (approximately at the top of the Whirlpool Rapids) did the Falls assume the profile with which we now associate them.

Why did it come to pass?

The problems raised by the Niagara gorge were observed and studied from an early date, but such is not the case for the Niagara River as a whole. This swiftly flowing body of water is more like a strait than a river: it carries as much water at its head as at its mouth; it has no well-defined valley with the exception of the gorge; it has no significant tributaries; it is,



ABOVE *The first accurate portrayal of the Canadian Falls was made in 1827 by Captain Basil Hall, a British Army Officer. The photograph* BELOW *was made in 1895 from approximately the same point. Note how the horseshoe notch has developed in the interval. To make his sketch, Captain Hall used a camera lucida—an instrument which projected an image of the falls, through a lens, directly onto his drawing paper.*



as Hennepin noted, "such a big river with no mountains". The same can be said of the other rivers of the Great Lakes system. Their origin lies in the Ice Age.

Somewhat less than one million years ago, massive glaciers spread out to cover most of the North American continent above the 40th parallel. Eventually they retreated, but then advanced again. The cycle occurred four times in all; most of what we know about the glacial history of southern

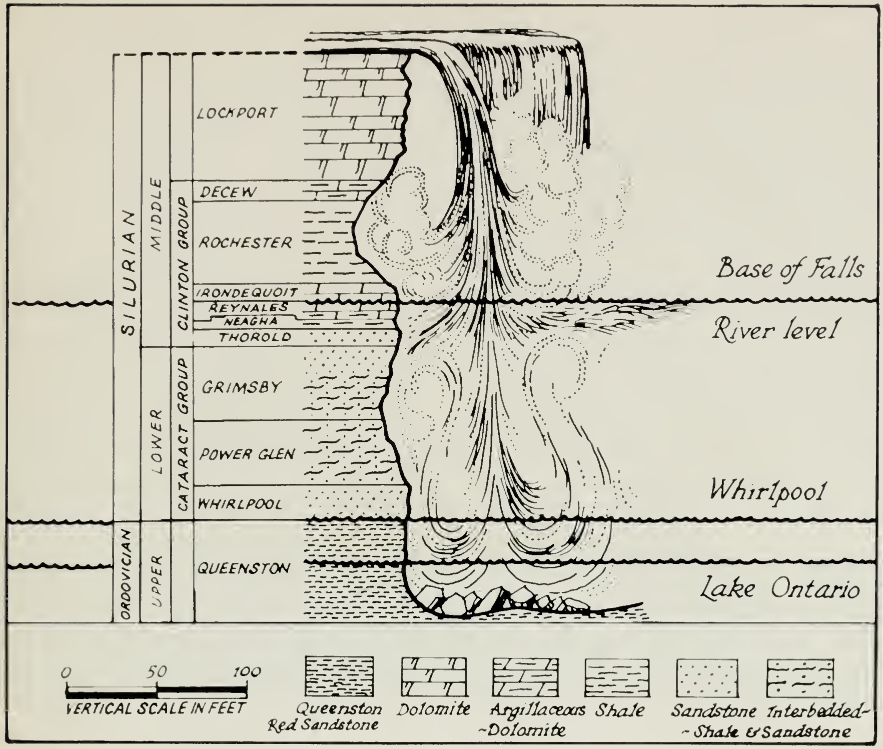
Ontario concerns the last advance and the last retreat. The final withdrawal in eastern North America began about 20,000 years ago, from south of Lake Erie. As the icefields drew back across the basins of the Great Lakes, the meltwaters became trapped between the high land around each lake basin and the margins of the glaciers. These ice margins changed continuously, either by melting or by a re-advance of the glaciers. As a result, there was in each lake basin an everchanging succession of lakes, from which evolved the ones we know today. Shifting patterns in the lakes were accompanied by changes in the rivers connecting them.

In the Erie basin the first lakes drained southwest to the Mississippi Valley. But as the ice front lying to the south of the Lake Ontario basin retreated northward, the waters of the Erie basin began to run eastward along the margin of the glacier, and then via Syracuse, N.Y., and the Mohawk and Hudson River valleys to the Atlantic. Further retreat of the ice front in the Erie and Ontario basins exposed the Niagara escarpment, and so these two basins became separated.

Immediately after the Niagara escarpment was uncovered, a lake—called Lake Tonawanda—developed between it and Lake Erie. The northern border of this body of water lay a few miles south of, and parallel to, the escarpment. Tonawanda was a peculiar lake in that it had six separate outlets, all of them draining northward and pouring over the escarpment into Lake Iroquois, the ancestor of Lake Ontario. The largest and westernmost of these spillways, the Lewiston, became the Niagara River.

While Lake Iroquois occupied the Ontario basin, the upper Great Lakes consisted of one huge single lake, called Lake Algonquin. Its waters combined with those of the Erie basin to begin the process of gorge-cutting at Niagara. As the glaciers continued to retreat across southern Ontario, Lake Algonquin found new outlets: at times its waters drained through the Erie basin, but at other times they did not. Thus the volume of water passing down the Niagara River varied considerably during its history. As the flow increased or slackened, so did the power of the river to erode the rock; the narrow and broad sections of the gorge are, then, nothing less than a record of smaller and greater volumes of water which poured over the Falls at various times.

One big puzzle in the history of the Niagara River still remains unsolved—the buried gorge which runs from the Whirlpool to a large embayment in the escarpment in the vicinity of the village of St. Davids. Its presence was discovered from the lack of outcrop in the Whirlpool basin, and confirmed by drilling. The gorge contains unconsolidated deposits which indicate that it was filled at least in part during a time of glacial advance. Material indicating a glacial advance has also been identified from borings for the bridge foundations at the upper end of the Whirlpool Rapids Gorge. Thus it appears that the St. Davids Gorge extended well upstream, and that



Tumbling waters—above the surface and in the plunge pool below—cut away the shales and sandstones of the lower strata until the harder caprock, undermined, collapses. Only the upper rocky layers can be seen at the Falls. The entire sequence of strata is visible at the northern end of the gorge, where the river has dropped to the level of Lake Ontario.

the present Niagara River has re-excavated part of it. This interpretation throws a new light on the whole history of the Niagara River: it suggests that an ancestral river extending from some unidentified spot once flowed through the present Whirlpool Rapids Gorge and the St. Davids Gorge into an ancestral body of water in the Lake Ontario basin. With a glacial re-advance, this path became filled with mud, gravel and clay; then, with the final retreat of the ice, and beginning with the Lewiston Spillway, the river cut a new route back to the Whirlpool, re-excavated the present Whirlpool Rapids Gorge, and finally cut out the Upper Great Gorge, at the head of which are the present Falls. Much remains to be learned however. New drilling to outline the shape and size of the buried gorge and to confirm its path below the escarpment, as well as coring to obtain suitable materials for dating the deposits, will be required before a solution is found to what appears to be the last remaining major problem in the history of the Niagara River. As this is being written some of this work is actually under way.

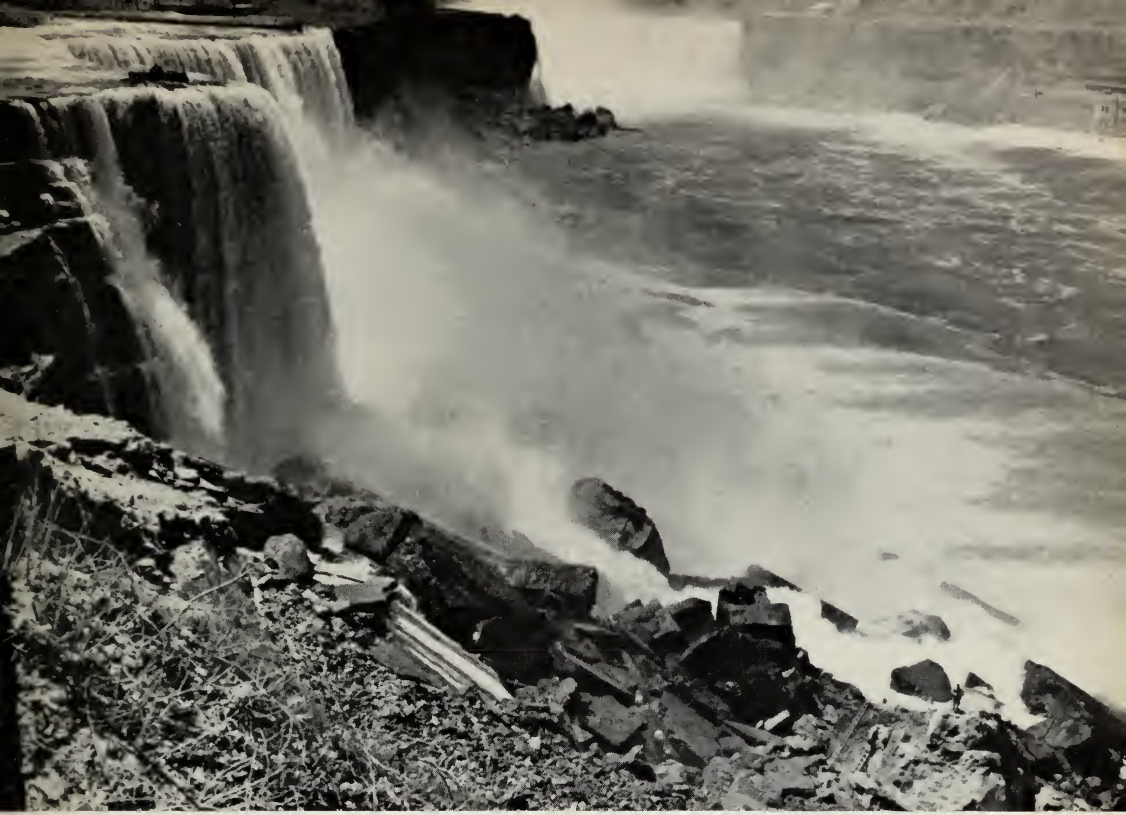
WHEN did it come to pass?

Perhaps no other natural phenomenon has kindled such consciousness of *time* as have Niagara Falls. Their age has been guessed, estimated and measured with varying results. The first statement as to the length of time required for the retrocession of the gorge—35,000 years—by Charles Lyell was really just an educated guess based on geological deductions.

The use of the gorge as a geological clock required knowledge of the rate of recession of the Falls. Rate measurement can be determined properly only from accurate surveys of their brink. The first accurate survey by triangulation was made under the direction of James Hall in 1842. The second was in 1875, and until that time no measured rate was available. The last Canadian survey was made in 1927 by W. H. Boyd for the government. The Table on page 15 summarizes some of the data from various surveys. Notice the tremendous variations in the figures; they are due to different methods of interpreting the results. The data also show how little the American Falls have receded; this feature can be related to the small volume of water—originally about five per cent of the river's total flow—that passes over this cataract.

To apply these rates over the length of the gorge in order to measure its age, certain geological factors must be evaluated. The more important of these include the height of the cataract, the width of the river, the volume of water, the thickness of the caprock and the variations in the underlying strata. It is no wonder that estimates for the age of the Falls, based on rates of erosion, vary from 7,000 to 100,000 years. The problem of course is complicated even further by the fact that a portion of the gorge—the Whirlpool Rapids section—was re-excavated through the removal of unconsolidated glacial deposits. Taylor and Kindle stated in 1913 that the making of the gorge may have taken from 20,000 to 30,000 or possibly 35,000 years, and added that with this approach, "It is not believed that more precise estimates can have any greater value." In other words the method can give only the order of magnitude, which means an age for the gorge in the tens of thousands of years and perhaps in the lower half of this order of magnitude (10,000 to 50,000 years).

The discovery of Carbon-14—a radioactive form of carbon—paved the way to a new and more precise method of finding out when the Niagara River came into being, and how long it has taken the Falls to recede from the edge of the Niagara escarpment. With this technique, a piece of fossil wood or other organic matter found in a deposit can be dated with some certainty if it is less than 50,000 years old. Such material has been found at three places associated with the Lake Iroquois shoreline. They have produced the following results: Hamilton City Hall, 11,510 ± 240 years ago; Lewiston, 12,660 ± 400 years ago; Lewiston, 12,080 ± 300 years ago.



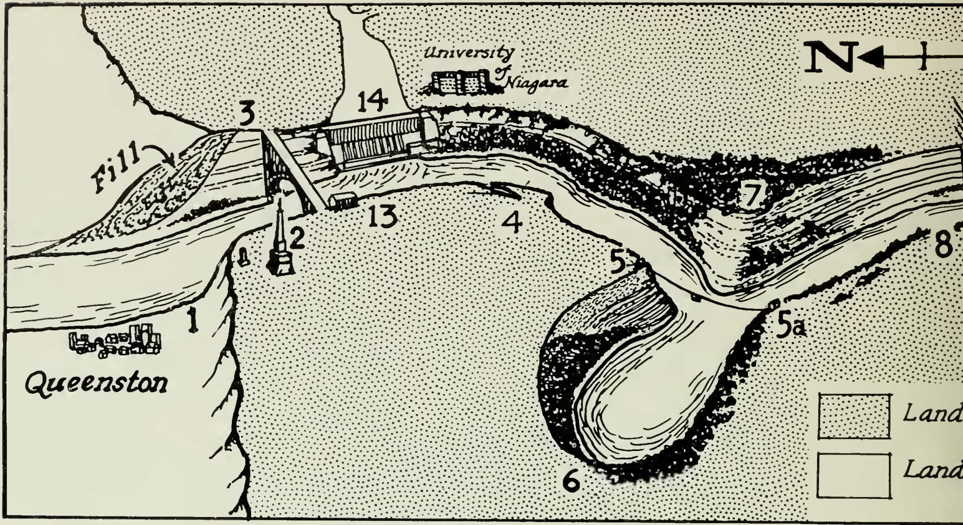
The view from Prospect Point in 1960. Note the jagged crest line of the American Falls. The talus, or debris, at the base of the cataract came from these indentations.

These figures suggest clearly that Lake Iroquois was present *about* 12,000 to 13,000 years ago. From the fact that Niagara Falls began gorge-cutting at the time Lake Iroquois occupied the Lake Ontario basin, geologists can say that Niagara Falls began its recession from the edge of the Niagara escarpment *about* 10,000 to 11,000 B.C. This figure is substantiated by Carbon-14 dates for ancestral lakes in the Erie basin. These data indicate that the Niagara Gorge was excavated at an average rate of about 3½ feet per year.

The Niagara River no longer measures the time "since the first rains fell on earth", but merely the time since thick glaciers departed from the Niagara Peninsula. This is but a minute fraction of the total time that geologists envisage for the history of the earth.

WHERE is the evidence?

The following descriptions of selected localities are brief and generalized, to help you on a geologically-oriented trip. Five areas have been chosen. It



is also worthwhile visiting either one or both of the electrical power generating stations—the Sir Adam Beck No. 2 Plant, operated by the Ontario Hydro-Electric Power Commission, and the Robert Moses Power Plant, operated by the Power Authority of the State of New York (Localities 13 and 14). Tours, motion pictures, and models are provided at both installations to illustrate how electrical power is generated in this area. They also depict some of the geographic and geologic features of Niagara.

THE NIAGARA ESCARPMENT—*Along Highway No. 8A between St. Davids and Queenston.*

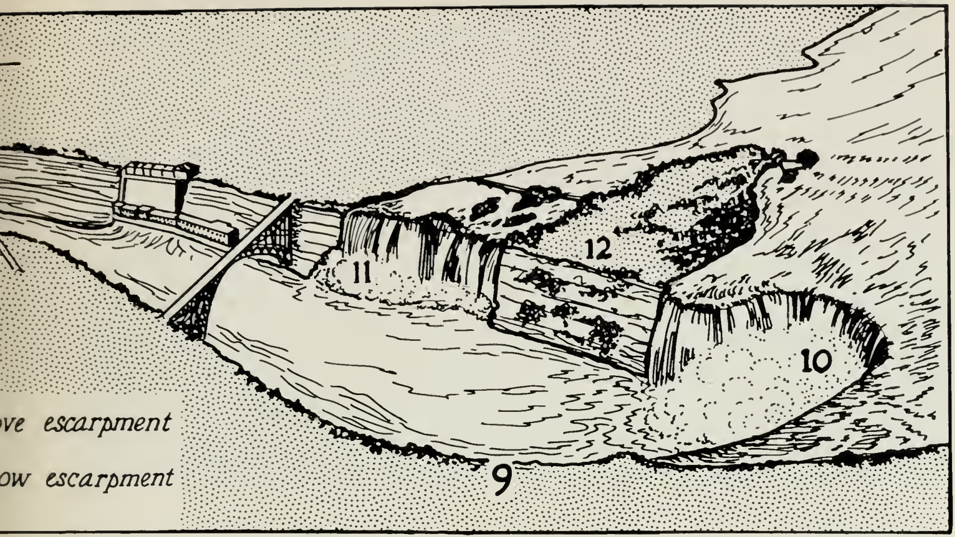
Highway No. 8A follows a course along the base of the Niagara escarpment and on top of a bluff, below which is a great expanse of flat land. The bluff marks the shoreline of Lake Iroquois, the ancestor of Lake Ontario. The flat land (a lake plain) was its bottom. When the lake was here about 12,000 years ago, the area must have looked much like the eastern shore of the Bruce Peninsula, where today the Niagara escarpment faces Georgian Bay.

The village of St. Davids is nestled in a valley where the brow of the escarpment bends southwards. This area marks the point where the buried St. Davids Gorge emerges from the Niagara escarpment.

THE MOUTH OF THE GORGE—*Locality 1: Approach to the Old Lewiston Bridge. Locality 2: Locust Grove, near Brock's Monument. Locality 3: The Robert Moses Parkway.*

From any of these localities you can obtain an excellent view of the spot where the Niagara River began its work of gorge-cutting. It was here that the waters of the ancestral Niagara River first tumbled from Lake Tonawanda, via the Lewiston Spillway, into the waters of Lake Iroquois.

The rocks exposed in the gorge are of sedimentary origin, and are about



400 million years old. The layers have been grouped into different formations. At the bottom, beginning at river level, are the red shales of the Queenston formation. Above them is the ledge-forming Whirlpool sandstone. Other strata are identified in the photograph on page 15. The Lockport dolomite is thin here as a result of erosion. It is thicker upstream.

THE NIAGARA GLEN—*Locality 4: Wintergreen and Foster's Flats.*

Wintergreen Flat is a promontory that juts out into the gorge; its surface is separated from the surrounding area by a steep slope about 25 feet high. This slope marks the shoreline of the ancestral Niagara River before the Falls cut back upstream from here.

At the downstream (northerly) end of Wintergreen Flat is a precipitous, undercut cliff of Lockport dolomite. A dry valley extends from the base of this cliff for 2,000 feet towards the river, to an area known as Foster's Flats. Much of this dry valley has been disturbed by the construction of the road on the west side of the gorge. As you survey this scene from the edge of Wintergreen Flat, you are actually standing on the spot where the waters of the ancestral Niagara River fell in a cataract to the river below them.

Below the cliffs of Wintergreen Flat is a chaotic accumulation of enormous blocks of dolomite. According to one theory, these blocks are the remains of an island which divided the ancestral Niagara River into two streams some 9,000 years ago. One branch of the old river flowed over Wintergreen Flat; the other, closer to the American side, was larger and more powerful, and so cut out the gorge; eventually it captured the waters that flowed over Wintergreen Flat. The island was reduced to rubble by the normal process of erosion.

The Niagara Glen demonstrates better than any other locality that the Falls once existed downstream from their present location. It also demonstrates that the ancestral Niagara River was broad above its successive cataracts, just as the present river is broad above the present cataracts. At one time the shoreline of the ancestral river could be traced almost continuously from the mouth of the gorge to the river banks above the American and Canadian Falls, but now it is recognizable at only a few localities.

THE WHIRLPOOL AND THE WHIRLPOOL RAPIDS GORGE—*Locality 5, 5A: The Cable Car Abutments. Locality 6: Viewpoint for the Whirlpool Rapids. Locality 7: Whirlpool Point State Park. Locality 8: Access to Boardwalk along Whirlpool Rapids.*

The Whirlpool occurs at a right-angled bend in the course of the Niagara River. The waters flow into it after a 52-foot drop through the Whirlpool Rapids Gorge, and swirl around in an anti-clockwise direction before continuing their course downstream. The water in the Whirlpool is at least 126 feet deep.

The bedrock is well exposed in the walls of the Whirlpool Basin beneath the abutments for the cable car landings. The contact between the red Queenston shale and the Whirlpool sandstone can be seen at the base of these cliffs when the water level is low. You can easily see, however, that in the northwest wall of the Whirlpool Basin, under Locality 6, no bedrock is exposed. This is the Whirlpool end of the buried St. Davids Gorge, which has been traced from this point to the Niagara escarpment at the village of St. Davids.

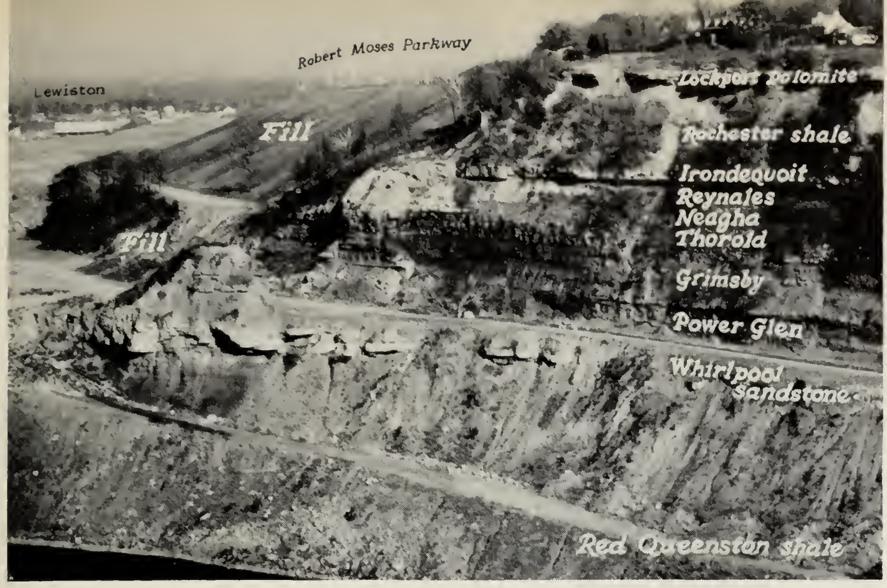
Whirlpool Point State Park (Locality 7) provides an excellent view of the buried gorge, and of the Whirlpool Rapids Gorge. As you look into this section of the river, notice how narrow it is. Note also how it is "on line" with the St. Davids Gorge, which is a point of evidence that both were cut out together and the present gorge re-excavated later. The rapids themselves are caused by large blocks of dolomite which have tumbled into the gorge. If possible you should take the elevator (Locality 8) down to the boardwalk that runs alongside them.

As you climb to the parking lot from the edge of the gorge at Whirlpool Point State Park, you are climbing the bank of the ancestral Niagara River. It can also be found at other spots around the Whirlpool Basin. Can you locate them?

THE CANADIAN AND AMERICAN FALLS—*Locality 9: The Power Plant beneath the Canadian Falls. Locality 10: The Canadian (Horseshoe) Falls. Locality 11: The American Falls. Locality 12: Goat Island.*

The Upper Great Gorge, extending approximately from the Rainbow Bridge to the Falls, has been excavated by the waters of the present Great Lakes. Go first to a point on the edge of the gorge above the mid-point of the power plant beneath the Canadian Falls (Locality 9). This is the approximate position of the Falls when Father Hennepin saw them in 1678. As you survey the scene you can actually visualize how much rock has been removed since that time.

There are many things to see and do around the Falls, but it is suggested you take the trip through Table Rock Scenic Tunnels beneath the Canadian Falls (Locality 10). Here you will appreciate the power of the falling water, and view for yourself the factors that contribute to the process of sapping. The winds and swirling waters behind the veil of falling water are impressive. Similar effects can be seen around the American Falls (Locality 11).



The strata of the Niagara escarpment stand exposed at the northern end of the Niagara Gorge opposite Locust Grove. These rocks were formed about 400 million years ago from the sediments and reefs of a prehistoric sea. The boundary between the red Queenston shale and the ledge-forming Whirlpool sandstone marks the contact between rocks of Ordovician and Silurian ages.

From Goat Island (Locality 12) you can observe the breadth of the river above the Falls, and particularly the slope of the bedrock surface in the river channel. Notice how it directs the flow towards the centre of the Horseshoe Falls. This is the main reason why the Horseshoe Falls receive more than 90 per cent of the total volume of the Niagara River, and have receded so much more rapidly than the American Falls.

SOME PUBLISHED RATES OF RECESSION IN FEET PER YEAR

FROM	TO	INTERVAL	AMERICAN FALLS	CANADIAN FALLS
1842	1875	33 years	0.74	2.01; 4.0–4.4
1842	1890	48	0.64	2.18
1842	1905	63	very little	3.8; 4.2; 5.3
1842	1911	69	—	5
1875	1886	11	0.11	1.86
1875	1905	30	—	5.6–6.6
1886	1890	4	1.65	5.01
1905	1927	22	very little	2.3
Average				3.78

N.B. Variations in rates over similar periods of time (e.g. 1842–1875) are due to different methods of interpreting the data obtained from the surveys. The Canadian Falls now have been "stabilized" by anti-erosion measures and the recession is said to have been reduced to one foot or less a year.

SOME DIMENSIONS OF THE NIAGARA RIVER AND ITS GORGE

(All figures in feet and variable within a few feet)

RIVER SEGMENT	LENGTH	GORGE WIDTH TOP MIN. MAX.	RIVER DEPTH MAX.	GORGE DEPTH AV.	RIVER BED BELOW L. ONTARIO MAX.
Above Falls—River 20 miles long; 3,000–7,000 feet wide.					
Upper Great Gorge	13,000	1,025–1,650	193	165	94
Whirlpool Rapids Gorge	4,000	750	Rapids	200	—
Whirlpool Basin	—	1,800	126	230	80
Lower Great Gorge:					
Ongiara Gorge	3,500	1,000–1,500	99	230	56
Niagara Glen Gorge	3,400	1,600–1,700	Rapids	250	—
Devil's Hole Gorge	2,700	1,500–1,600	70(?)	300	?
Old Narrow Gorge	5,700	1,200	63	300	60
Lewiston Branch Gorge	2,000	1,400	150	320	148
Queenston Pier	—	1,700	183	—	183
Opposite Lewiston	—	2,000	87	—	87
Below Falls—River 7 miles long; 2,000 feet wide.					

SLOPE OF THE NIAGARA RIVER

(All figures in feet and variable within a few feet)

	ABOVE SEA LEVEL	ABOVE L. ONTARIO	DROP
Lake Erie	572	325	—
Head of Upper Rapids	559	312	—
Drop of Upper Rapids	—	—	55
Canadian Falls (Average)	504	257	—
Drop of Canadian Falls (Average)	—	—	158
American Falls (Average)	512	265	—
Drop of American Falls (Average)	—	—	166
River Surface below Falls	346	99	—
River Surface at head of Whirlpool Rapids	345	98	—
Drop of Whirlpool Rapids	—	—	52
River Surface at Whirlpool	293	46	—
River at Queenston	248	1	—
Lake Ontario	247	—	—
Drop Lake Erie to Lake Ontario	—	—	325

SUGGESTED READING

BOYD, W. H. "A New Method of Determining the Rate of Recession of Niagara Falls", *Transactions of the Royal Society of Canada*, Section IV, 1928

DOW, C. M. *Anthology and Bibliography of Niagara Falls* (State of New York, 1921, 2 vol.)

GILBERT, G. K. *Rate of Recession of Niagara Falls* (Bulletin 306, United States Geological Survey, 1907)

GRABAU, A. W. *Guide to the Geology and Palaeontology of Niagara Falls and Vicinity* (Bulletin, New York State Museum, Vol. 45, No. 9, 1901)

HOUGH, JACK L. *Geology of the Great Lakes* (University of Illinois Press, 1958)

KINDLE, E. M. AND F. B. TAYLOR. *Niagara Folio* (No. 190, United States Geological Survey, 1913)

LEMON, R. R. H. *Fossils in Ontario* (Royal Ontario Museum, University of Toronto, 1965)

LYELL, CHARLES. *Travels in North America in the Years 1841–2; with Geological Observations on the United States, Canada and Nova Scotia* (Wiley and Putnam, N.Y., 1845)

SPENCER, J. W. W. *The Falls of Niagara* (Geological Survey of Canada, 1907)

TOVELL, WALTER M. AND P. F. KARROW. "Niagara Falls (Geology)", *A Naturalist's Guide to Ontario* (University of Toronto Press, 1964)

TOVELL, WALTER M. *The Niagara Escarpment* (Royal Ontario Museum, University of Toronto, 1965)